

# Outcome Based Education (OBE) Manual

Department of  
**Mechanical Engineering**

**Regulation : R24**

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## OVERVIEW

**Outcome Based Education (OBE)** is an educational model that forms the base of a quality education system. There is no single specified style of teaching or assessment in OBE. All educational activities carried out in OBE should help the students to achieve the set goals. The faculty may adapt the role of instructor, trainer, facilitator, and/or mentor, based on the outcomes targeted.

OBE enhances the traditional methods and focuses on what the Institute provides to students. It shows the success by making or demonstrating outcomes using statements “able to do” in favor of students. OBE provides clear standards for observable and measurable outcomes.

National Board of Accreditation (NBA) is an authorized body for the accreditation of higher education institutions in India. NBA is also a full member of the Washington Accord. NBA accredits programs and not the institutions.

Higher Education Institutions are classified into two categories by NBA

**Tier – 1:** Institutions consists of all IITs, NITs, Central Universities, State Universities and Autonomous Institutions. Tier –I institution can also claim the benefits as per the Washington Accord.

**Tier-2:** Institutions consist of affiliated colleges of universities.

What is Outcome Based Education (OBE)?

Institutions adopting OBE try to bring changes to the curriculum by dynamically adapting to the requirements of the different Stake holders like Students, Parents, Industry Personnel and Recruiters. OBE is all about feedback and outcomes.

Four levels of outcomes from OBE are:

1. Program Educational Objectives (PEOs)
2. Program Specific Outcomes (PSOs)
3. Program Outcomes (POs)
4. Course Outcomes (COs)

Why OBE?

1. International recognition and global employment opportunities.
2. More employable and innovative graduates with professional and soft skills, social responsibility and ethics.
3. Better visibility and reputation of the technical institution among stakeholders.
4. Improving the commitment and involvement of all the stakeholders.
5. Enabling graduates to excel in their profession and accomplish greater heights in their careers.
6. Preparing graduates for the leadership positions and challenging them and making them aware of the opportunities in the technology development.

## Benefits of OBE

**Clarity:** The focus on outcome creates a clear expectation of what needs to be accomplished by the end of the course.

**Flexibility:** With a clear sense of what needs to be accomplished, instructors will be able to structure their lessons around the student's needs.

**Comparison:** OBE can be compared across the individual, class, batch, program and institute levels.

**Involvement:** Students are expected to do their own learning. Increased student's involvement allows them to feel responsible for their own learning, and they should learn more through this individual learning.

- Teaching will become a far more creative and innovative career
- Faculty members will no longer feel the pressure of having to be the “source of all knowledge”.
- Faculty members shape the thinking and vision of students towards a course.

## India, OBE and Accreditation:

From 13 June 2014, India has become the permanent signatory member of the Washington Accord Implementation of OBE in higher technical education also started in India. The National Assessment and Accreditation Council (NAAC) and National Board of Accreditation (NBA) are the autonomous bodies for promoting global quality standards for technical education in India. NBA has started accrediting the programs running with OBE from 2013.

The National Board of Accreditation mandates establishing a culture of outcome-based education in institutions that offer Engineering, Pharmacy, and Management program Reports of outcome analysis help to find gaps and carryout continuous improvements in the education system of an Institute, which is very essential.

# 1. Vision, Mission, Quality Policy, Philosophy & Core Values

## Vision

“The Mechanical Engineering Department strives to foster innovation, excellence, and leadership in education and research, advancing sustainable development globally.”

## Mission

M1: To provide innovative and sustainable technology solutions to solve a wide range of complex scientific and technological challenges in the Mechanical Engineering field.

M2: To enhance employability, leadership skills, and research capabilities through industry collaboration and experiential learning.

M3: To nurture students as ethical and resilient professionals committed to lifelong learning.

M4: To promote excellence in emerging interdisciplinary fields to support sustainable global progress.

## Quality Policy

Our policy is to nurture and build diligent and dedicated community of engineers providing a professional and unprejudiced environment, thus justifying the purpose of teaching and satisfying the stake holders.

A team of well qualified and experienced professionals ensure quality education with its practical application in all areas of the Institute.

## Philosophy

The essence of learning lies in pursuing the truth that liberates one from the darkness of ignorance and Marri Laxman Reddy Institute of Technology and management firmly believes that education is for liberation.

Contained therein is the notion that engineering education includes all fields of science that plays a pivotal role in the development of world-wide community contributing to the progress of civilization. This institute, adhering to the above understanding, is committed to the development of science and technology in congruence with the natural environs. It lays great emphasis on intensive research and education that blends professional skills and high moral standards with a sense of individuality and humanity. We thus promote ties with local communities and encourage transnational interactions in order to be socially accountable. This accelerates the process of transfiguring the students into complete human beings making the learning process relevant to life, instilling in them a sense of courtesy and responsibility.

## Core Values

**Excellence:** All activities are conducted according to the highest international standards.

**Integrity:** Adheres to the principles of honesty, trustworthiness, reliability, transparency and accountability.

**Inclusiveness:** To show respect for ethics, cultural and religious diversity, and freedom of thought.

**Social Responsibility:** Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

**Innovation:** Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

## 2. Program Educational Objectives (PEOs)

**Program Educational Objectives (PEOs)** should be defined by the PAQIC after taking feedback from all stake holders. PEOs are a promise by the department to the aspiring students about what they will achieve once they join the program. PEO assessment is not made compulsory by NBA as it is quite difficult to measure in the Indian context. NBA assessors usually do not ask for PEO assessment. PEOs are about professional and career accomplishment after 4 to 5 years of graduation. PEOs can be written from different perspectives like Career, Technical Competency, and Behavior. While writing the PEOs, do not use technical terms as it will be read by prospective students who want to join the program. Three to five PEOs are recommended.

**Program Educational Objective - I:** To develop a strong foundation in mechanical engineering principles for analyzing, designing, and innovating engineering solutions.

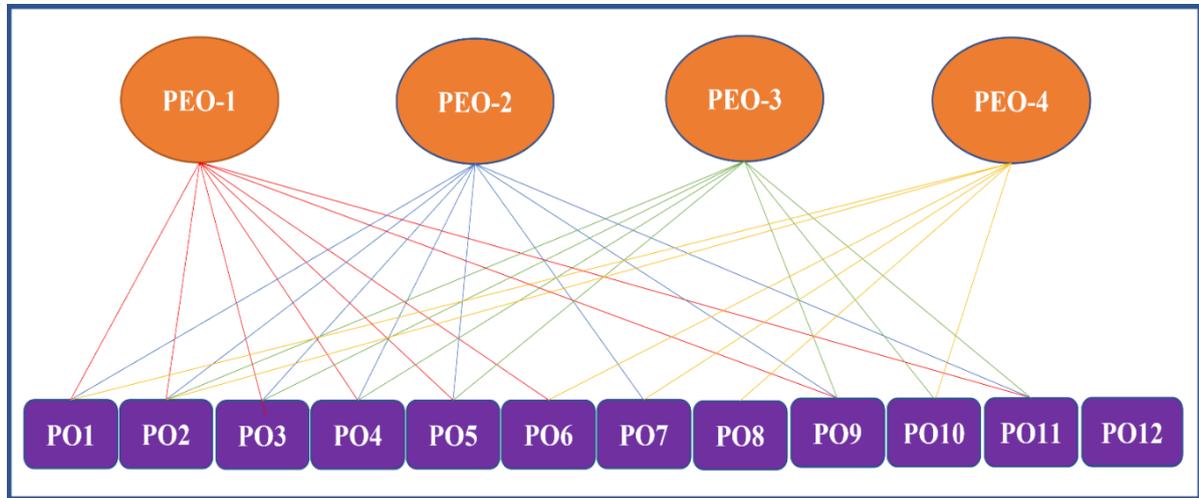
**Program Educational Objective - II:** To equip graduates with skills and knowledge to address industry challenges and contribute effectively to societal needs.

**Program Educational Objective - III:** To foster the ability to collaborate across multidisciplinary teams while upholding professional ethics and responsibility.

**Program Educational Objective - IV:** To promote lifelong learning, adaptability, and leadership skills for continuous personal and professional growth in a dynamic environment.

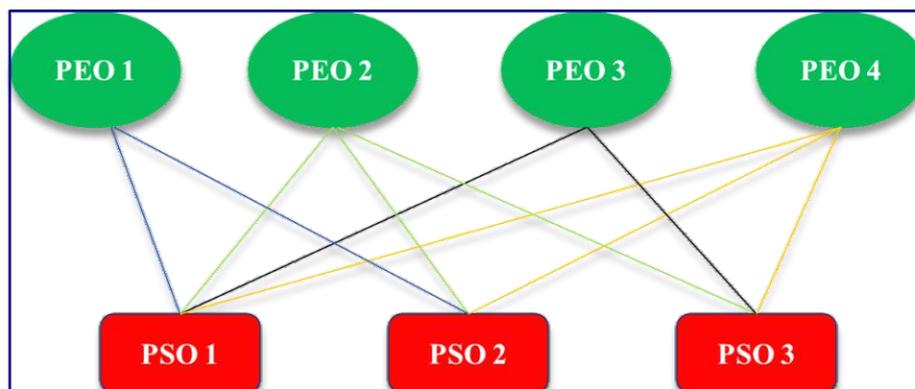
2.1. Mapping of program educational objectives to program outcomes and program specific outcomes:

The following Figure 1 shows the correlation between the PEOs and the POs



PEO-I	PEO-II	PEO-III	PEO-IV
PO:1,2,3,4,5,6,9,11	PO:1,2,3,4,5,7,9,11	PO:2,3,4,5,9,10,11	PO:1,2,6,7,8,10,

FIGURE1: Correlation between the PEOs and the Pos



The following Figure2 shows the correlation between the PEOs and the PSOs

PEO-I	PEO-II	PEO-III	PEO-IV
PSO:1,2	PSO:1,2,3	PSO:1,2,3	PSO:1,2,3

FIGURE2: Correlation between the PEOs and the PSOs

### 3. Program Outcomes (POs)

A Program Learning Outcome is broad in scope and describes what a student should be able to do at the end of the program. POs are aligned with the graduate attributes specified in the **Washington Accord**. POs should be specific, measurable, and achievable.

The **NBA** has defined **12 POs**, which are common for all institutions in India.

In the syllabus book given to students, there should be a clear mention of **course objectives** and **course outcomes**, along with a **CO-PO course articulation matrix** for all the courses.

<b>B. Tech (MECH) – PROGRAM OUTCOMES (PO's)</b>	
A graduate of the Mechanical Engineering Program will be demonstrated:	
<b>PO1</b>	<b>Engineering Knowledge:</b> Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
<b>PO2</b>	<b>Problem Analysis:</b> Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
<b>PO3</b>	<b>Design/Development of Solutions:</b> Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.
<b>PO4</b>	<b>Conduct Investigations of Complex Problems:</b> Use research-based knowledge and research methods, including the design of experiments, analysis and interpretation of data, and synthesis of information, to provide valid conclusions.
<b>PO5</b>	<b>Modern tool usage:</b> Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
<b>PO6</b>	<b>The Engineer and Society:</b> Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues, and the consequent responsibilities relevant to professional engineering practice.
<b>PO7</b>	<b>Environment and Sustainability:</b> Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate knowledge of and the need for sustainable development.
<b>PO8</b>	<b>Ethics:</b> Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.
<b>PO9</b>	<b>Individual and Teamwork:</b> Function effectively as an individual, as well as a member or leader in diverse teams and multidisciplinary settings.

<b>PO10</b>	<b>Communication:</b> Communicate effectively on complex engineering activities with the engineering community and society at large. This includes the ability to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions
<b>PO11</b>	<b>Project Management and Finance:</b> Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work as a member and leader in a team to manage projects in multidisciplinary environments.
<b>PO12</b>	<b>Life-Long Learning:</b> Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

#### 4. Program Specific Outcomes (PSOs)

Program Specific Outcomes (PSOs) are statements that describe what the graduates of a specific engineering program should be able to do.

A list of PSOs written for the Department of Mechanical Engineering is given below.

<b>B. Tech (MECH) – PROGRAM SPECIFIC OUTCOMES (PSO's)</b>	
A graduate of the Mechanical Engineering Program will demonstrate:	
<b>PSO1</b>	Understand, analyse, apply, design and develop engineering systems adopting thermal, design and manufacturing concepts.
<b>PSO2</b>	Utilize computational and design tools for efficient product development in addressing industrial challenges.
<b>PSO3</b>	Make use of acquired knowledge and entrepreneurial skills to create innovative solutions that address societal needs while promoting sustainable growth.

## 5. Relation between the Program Educational Objectives and the POs

Broad relationship between the program objectives and the program outcomes is given in the following Table below:

PEO's→ ↓PO's		(1) Success in Mechanical Engineering	(2) Industrial awareness and research	(3) Successful employment and professional ethics	(4) Being a leader professional and societal environment
<b>PO1</b>	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	1		1
<b>PO2</b>	Identify, formulate, review research literature, and analyse complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	3	1	1
<b>PO3</b>	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, as well as cultural, societal, and environmental considerations.	3	1	2	
<b>PO4</b>	Use research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	1	3	1	

<b>PO5</b>	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities with an understanding of the limitations.	2	1	2	
<b>PO6</b>	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.	1			3
<b>PO7</b>	Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of and need for sustainable development.		1		3
<b>PO8</b>	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.				2
<b>PO9</b>	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	1	1	2	
<b>PO10</b>	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.			2	3
<b>PO11</b>	Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work as a member and leader in a team, to manage projects in multidisciplinary environments.	1	1	3	

<b>PO12</b>	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.				
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## 6. Relation between the Program Specific Outcomes and the Program Educational Objectives

PEO's → ↓ PSO's		(1) Success in Mechanical Engineering	(2) Industrial awareness and research	(3) Successful employment and professional ethics	(4) Being a leader professional and societal environment
<b>PSO 1</b>	Understand, analyse, apply, design and develop engineering systems adopting thermal, design and manufacturing concepts.	3	2	1	1
<b>PSO 2</b>	Utilize computational and design tools for efficient product development in addressing industrial challenges.	2	2	2	2
<b>PSO 3</b>	Make use of acquired knowledge and entrepreneurial skills to create innovative solutions that address societal needs while promoting sustainable growth.	1	2	3	3

Relationship between Program Specific Outcomes and Program Educational Objectives Key: 3 = High; 2 = Medium; 1 = Low

**Note:**

- The assessment process of POs and PSOs can be direct or indirect.
- The direct assessment will be done through interim assessment by conducting continuous internal exam and semester end exams.
- The indirect assessment on the other hand could be done through student's program exit questionnaire, alumni survey and employment survey.

## 7. Bloom's Taxonomy

Bloom's taxonomy is considered the global language for education. Bloom's Taxonomy is frequently used by teachers in writing course outcomes as it provides a ready-made structure and a list of action verbs. The stages ascend in complexity and what they demand of students.

First, students need to simply remember information provided to them—but reciting something doesn't demonstrate having learned it, only memorization. With understanding comes the ability to explain the ideas and concepts to others. The students are then challenged to apply the information and use it in new ways, helping to gain a deeper understanding of previously covered material and demonstrating it moving forward.

Questioning information is a vital part of learning, and both analysis and evaluation do just this. Analysing asks a student to examine the information in a new way, and evaluation demands the student appraise the material in a way that lets them defend or argue against it as they determine.

The final step in the revised taxonomy is creating, which entails developing a new product or point of view. How does this learned information impact your world? How can it be used to impact not just your education but the way you interact with your surroundings? By utilizing Bloom's Taxonomy, students are not going to forget the information as soon as the class ends rather, they retain and apply the information as they continue to grow as a student and in their careers, staying one step ahead of the competition.

### 7.1. Incorporating Critical Thinking Skills into Course Outcome Statements

Many faculty members choose to incorporate words that reflect critical or higher-order thinking into their learning outcome statements. Bloom (1956) developed a taxonomy outlining the different types of thinking skills people use in the learning process. Bloom argued that people use different levels of thinking skills to process different types of information and situations. Some of these are basic cognitive skills (such as memorization) while others are complex skills (such as creating new ways to apply information). These skills are often referred to as critical thinking skills or higher-order thinking skills.

Bloom proposed the following taxonomy of thinking skills. All levels of Bloom's taxonomy of thinking skills can be incorporated into expected learning outcome statements. Recently, Anderson and Krathwohl (2001) adapted Bloom's model to include language that is oriented towards the language used in expected learning outcome statements. A summary of

Anderson and Krathwohl's revised version of Bloom's taxonomy of critical thinking is provided in Figure 3.



FIGURE3: Revised version of Bloom's taxonomy

## 7.2. Definitions of the different levels of thinking skills in Bloom's taxonomy:

**Remember:** Recalling relevant terminology, specific facts, or different procedures related to information and/or course topics. At this level, a student can remember something but may not really understand it.

**Understand** – The ability to grasp the meaning of information (facts, definitions, concepts, etc.) that has been presented.

**Apply** – Being able to use previously learned information in different situations or in problem-solving.

**Analyze**– The ability to break information down into its component parts. Analysis also refers to the process of examining information in order to make conclusions regarding cause and effect, interpreting motives, making inferences, or finding evidence to support statements/arguments.

**Evaluate** – Being able to judge the value of information and/or sources of information based on personal values or opinions.

**Create**– The ability to creatively or uniquely apply prior knowledge and/or skills to produce new and original thoughts, ideas, processes, etc. At this level, students are involved in creating their own thoughts and ideas.

## 7.3. List of Action Words Related to Critical Thinking Skills

Here is a list of action words that can be used when creating the expected student learning outcomes related to critical thinking skills in a course. These terms are organized according

to the different levels of higher-order thinking skills contained in Anderson and Krathwohl's (2001) revised version of Bloom's taxonomy.

Here is the revised Bloom's document with action verbs, which we frequently refer to while writing COs for our courses.

**The cognitive process dimensions - categories:**

Lower Order of Thinking (LOT)			Higher Order of Thinking (HOT)		
Remember	Understand	Apply	Analyze	Evaluate	Create
Interpreting	Recognizing	Executing	Differentiating	Checking	Planning
Illustrating	(identifying)	Implementing	Organizing	(Coordinating)	Generating
Classifying	Recalling		Attributing	detecting,	Producing
Summarizing	(retrieving)			testing,	(constructing)
Inferring				monitoring)	
(concluding)				Critiquing	
comparing				(judging)	
explaining					

The Knowledge Dimension			
Concrete Knowledge → Abstract knowledge			
Factual	Conceptual	Procedural	Metacognitive
<ul style="list-style-type: none"> <li>• Knowledge of terminologies</li> <li>• Knowledge of specific details and elements.</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge of classifications and categories</li> <li>• Knowledge of principles and generalizations</li> <li>• Knowledge of theories, models and structures</li> </ul>	<ul style="list-style-type: none"> <li>• Knowledge of subject specific skills and algorithms</li> <li>• Knowledge of subject specific techniques and methods</li> <li>• Knowledge of criteria for determining when to use appropriate procedures</li> </ul>	<ul style="list-style-type: none"> <li>• Strategic Knowledge</li> <li>• Knowledge about cognitive task, including gap appropriate contextual and conditional Knowledge</li> <li>• Self-Knowledge</li> </ul>

## Action Verbs for Course Out comes

Lower Order of Thinking (LOT)				Higher Order of Thinking (HOT)		
Definitions	Remember	Understand	Apply	Analyze	Evaluate	Create
<b>Bloom's Definition</b>	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and Stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.
<b>Verbs</b>	<ul style="list-style-type: none"> <li>• Choose</li> <li>• Define</li> <li>• Find</li> <li>• How</li> <li>• Label</li> <li>• List</li> <li>• Match</li> <li>• Extend</li> </ul>	<ul style="list-style-type: none"> <li>• Classify</li> <li>• Compare</li> <li>• Contrast</li> <li>• Demonstrate</li> <li>• Explain</li> <li>• Illustrate</li> <li>• Infer</li> <li>• Interpret</li> </ul>	<ul style="list-style-type: none"> <li>• Apply</li> <li>• Build</li> <li>• Choose</li> <li>• Construct</li> <li>• Develop</li> <li>• Interview</li> <li>• Make use of</li> <li>• Model</li> </ul>	<ul style="list-style-type: none"> <li>• Analyze</li> <li>• Assume</li> <li>• Categorize</li> <li>• Classify</li> <li>• Compare</li> <li>• Discover</li> <li>• Dissect</li> <li>• Distinguish</li> </ul>	<ul style="list-style-type: none"> <li>• Agree</li> <li>• Appraise</li> <li>• Assess</li> <li>• Award</li> <li>• Choose</li> <li>• Criticize</li> <li>• Decide</li> <li>• Deduct</li> <li>• Importance</li> </ul>	<ul style="list-style-type: none"> <li>• Adapt</li> <li>• Build</li> <li>• Solve</li> <li>• Choose</li> <li>• Combine</li> <li>• Invent</li> <li>• Compile</li> <li>• Compose</li> <li>• Construct</li> </ul>

<b>Verbs</b>	• Name	• Outline	• Organize	• Divide	• Defend	• Create
	• Omit	• Relate	• Plan	• Examine	• Determine	• Design
	• Recall	• Rephrase	• Select	• Function	• Disprove	• Develop
	• Relate	• Show	• Solve	• Inference	• Estimate	• Estimate
	• Select	• Summarize	• Utilize	• Inspect	• Evaluate	• Formulate
	• Show	• Translate	• Identify	• List Motive	• Influence	• Happen
	• Spell	• Experiment with	• Interview	• Simplify	• Interpret	• Imagine
	• Tell	• Illustrate	• Make use of	• Survey	• Judge	• Improve
	• What	• Infer	• Model	• Take part in	• Justify	• Makeup
	• When	• Interpret	• Organize	• Test for Theme	• Mark	• Maximize
	• Where	• Outline	• Plan	• Conclusion	• Measure	• Minimize
	• Which	• Relate	• Select	• Contrast	• Opinion	• Modify
	• Who	• Rephrase	• Solve		• Perceive	• Original
	• Why	• Show	• Utilize		• Prioritize	• Originate
		• Summarize	• Identify		• Prove	• Plan
		• Translate			• Criteria	• Predict
		• Experiment with			• Criticize	• Propose
				• Compare	• Solution	
				• Conclude		

## 8. Guidelines for writing Course Outcome Statements:

**Well-written course outcomes involve the following parts:**

1. Action verb
2. Subject content
3. Level of achievement as per BTL
4. Modes of performing task (if applicable)

### 8.1. Course Outcomes (COs)

A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes, remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc., that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what

specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

## 8.2. Developing Course Outcomes

When creating course outcomes consider the following guidelines as you develop them either individually or as part of a multi-section group:

Limit the course outcomes to 5-6 statements for the entire course [more detailed outcomes can be developed for individual units, assignments, chapters, etc. if the instructor(s) wish (es)].

Focus on overarching knowledge and/or skills rather than small or trivial details.

Emphasize knowledge and skills that are central to the course topic and/or discipline.

Create statements that have a student focus rather than an instructor-centric approach. (Example: **Student-focused outcome:** “Upon completion of this course, students will be able to list the names of the 28 states and 8 union territories.”)

**Instructor-centric objective (to avoid):** “One objective of this course is to teach the names of the 28 states and 8 union territories.”).

**Focus on the learning** that results from the course rather than describing activities or lessons that are in the course.

**Incorporate and/or reflect** the institutional and departmental mission.

**Include various ways for students to show success** (e.g., outlining, describing, modeling, depicting, etc.) rather than using a single statement such as “At the end of the course, students will know” as the stem for each expected outcome statement.

**When developing learning outcomes, here are the core questions to ask yourself:**

- What do we want students in the course to learn?
- What do we want the students to be able to do?
- Are the outcomes observable, measurable, and able to be performed by the students?

**Course outcome statements at the course level describe:**

- What faculty members want students to know at the end of the course **AND**
- What faculty members want students to be able to do at the end of the course.

**Course outcomes have three major characteristics:**

- They specify an action by the students/learners that is **observable**.
- They specify an action by the students/learners that is **measurable**.
- They specify an action that is **done by the students/learners** rather than the faculty members.

**Effectively developed expected learning outcome statements should possess all three of these characteristics.**

When this is done, the expected learning outcomes for a course are designed so that they can be assessed. When stating expected learning outcomes, it is important to use **verbs that describe exactly what the student(s)/learner(s) will be able to do upon completion of the course.**

### 8.3. Relationship of Course Outcome to Program Outcome

**Learning outcomes formula:**

**STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE**

The Course Outcomes need to link to the Program Outcomes.

For example, you can use the following template to help you write an appropriate course level learning outcome.

*“Upon completion of this course students will be able to (knowledge, concept, rule or skill you expect them to acquire) by (how will they apply the knowledge or skill/how will you assess the learning).”*

### 8.4. Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learning your course.
- A realigned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviors.
- Arrases able through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language.

### 8.5. Examples of Effective Course Outcomes

After successful completion of the course, Students will be able to:

- Critically review the methodology of a research study published in a scholarly sociology journal.
- Design a web site using HTML and Java Script.
- Describe the contributions of women in American history.
- Recognize the works of major Re-naissance artists.
- Facilitating a group to achieve agreed – Up on goals.

- Determine the appropriate statistical procedures to analyze the results of simple experiments.
- Develop an individual learning plan for a child with a learning disability.
- Produce a strategic plan for a small manufacturing business.
- Analyze each character's motivation and portray that character before an audience.
- Differentiate among five major approaches to literary analysis.
- List the major ethical issues one must consider when planning a human-subjects study.
- Locate and critically evaluate information on current political issues on the Web.
- List and describe the functions of the major components of the human nervous system.
- Correctly classify rock samples found in...
- Conduct a systems analysis of a group interaction.
- Demonstrate active listening skills when interviewing clients.
- Apply social psychological principles to suggest solutions to contemporary social problems.

A more detailed model for stating learning objectives requires that objectives have three parts: a condition, an observable behavior, and a standard.

The table below provides three examples.

S. No	Condition	Observable Behavior	Standard
1	Given a list of drugs	The student will be able to classify each item as amphetamine or barbiturate.	With at least 70% accuracy
2	Immediately following a fifteen-minute discussion on a topic.	The student will be able to summarize in writing the major issues being discussed.	Mentioning at least three of the five major topics.
3	Given an algebraic equation with one unknown.	The student will be able to correctly solve a simple linear equation.	Within a period of five minutes.

The following examples describe a course outcome that is not measurable as written, an explanation for why the course outcome is not considered measurable, and a suggested edit that improves the course outcome

Original course outcome	Evaluation of language used in this course outcome	Improved course outcome
Explore in depth the literature on an aspect of teaching strategies.	Exploration is not a measurable activity, but the quality of the product of exploration would be measurable with a suitable rubric.	Upon completion of this course, the students will be able to: write a paper based on an in-depth exploration of the literature on an aspect of teaching strategies.

**Examples those are TOO general and VERY HARD to measure...**

- ...will appreciate the benefits of learning a foreign language.
- ...will be able to access resources at the Institute library.
- ...will develop problem-solving skills.
- ...will have more confidence in their knowledge of the subject matter.
- **Examples those are still general and HARD to measure...**
- ...will value knowing a second language as a communication tool.
- ...will develop and apply effective problem-solving skills that will enable one to adequately navigate through the proper resources within the institute library.
- ...will demonstrate the ability to resolve problems that occur in the field.
- ...will demonstrate critical thinking skills, such as problem-solving as it relates to social issues.
- **Examples those are SPECIFIC and relatively EASY to measure...**
- ...will be able to read and demonstrate good comprehension of text in areas of the student's interest or professional field.
- ...will demonstrate the ability to apply basic research methods in psychology, including research design, data analysis, and interpretation.
- ...will be able to identify environmental problems, evaluate problem-solving strategies, and develop science-based solutions.
- ...will demonstrate the ability to evaluate, integrate, and apply appropriate information from various sources to create cohesive, persuasive arguments, and to propose design concepts.
- **An Introspection - Examine Your Own Course Outcomes**
- If you have written statements of broad course goals, take a look at them. If you do not have a written list of course goals, reflect on your course and list the four to six most important student outcomes you want your course to produce.
- Look over your list and check the one most important student outcome. If you could only achieve one outcome, which one would it be?

- Look for your outcome on the list of key competencies or outcomes society is asking us to produce. Is it there? If not, is the reason a compelling one?
- Check each of your other “most important” outcomes against the list of outcomes. How many are on the list of key competencies?
- Take stock. What can you learn from this exercise about what you are trying to accomplish as a teacher? How clear and how important are your statements of outcomes for your use and for your students? Are they very specifically worded to avoid misunderstanding? Are they supporting important needs on the part of the students?

### **Write Your Course Outcomes!**

One of the first steps you take in identifying the expected learning outcomes for your course is identifying the purpose of teaching the course. By clarifying and specifying the purpose of the course, you will be able to discover the main topics or themes related to students’ learning. Once discovered, these themes will help you to outline the expected learning outcomes for the course.

Ask yourself:

- What role does this course play within the program?
- How is the course unique or different from other courses?
- Why should/do students take this course? What essential knowledge or skills should they gain from this experience?
- What knowledge or skills from this course will students need to have mastered to perform well in future classes or jobs?
- Why is this course important for students to take?

## **8.6. CO-PO Course Articulation Matrix (CAM) Mapping**

A **Course Articulation Matrix** shows the educational relationship (Level of Learning achieved) between course outcomes and program outcomes for a course. This matrix strongly indicates whether the students are able to achieve the course learning objectives. The matrix can be used for any course and is a good way to evaluate a course syllabus.

**Table 1** provides information about the action verbs used in the Program Outcomes (POs) and the nature of POs, stating whether the POs are technical or non-technical.

You need to understand the intention of each PO and the **Bloom’s Taxonomy level** to which each of the section verbs in the POs correlates. Once you have understood the POs, you can write the **Course Outcomes (COs)** for a course and see to what extent each of those COs correlates with the POs.

TABLE 9: Process for mapping the values for CO-PO Matrix

Experiential learning	Experiential learning	Experiential learning	Experiential learning	Experiential learning
<b>Technical</b>	PO1	Apply	L3	Bloom's L1 to L4 for theory courses. Bloom's L1 to L5 for laboratory courses. Bloom's L1 to L6 for Project work, experiential learning
	PO2	Identify	L2	
		Formulate	L6	
		Review	L2	
	PO3	Design	L6	
		Develop	L3, L6	
	PO4	Analyze	L4	
		Interpret	L2, L3	
		Design	L6	
	PO5	Create	L6	
		Select	L1, L2, L6	
		Apply	L3	
	<b>Non-Technical</b>	PO6	<b>Thumb Rule:</b> If Bloom's L1 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 1. If Bloom's L2 to L3 Action Verbs of a CO: Correlates with Any of PO6 to PO12, then assign 2. If Bloom's L4 to L6 Action Verbs of a CO: Correlates with any of PO6 to PO12, then assign 3	
PO7				
PO8				
PO9				
PO10				
PO11				
PO12				

At the end, the Program Outcomes (POs) can be calculated using various descriptors that you may define. The mapping of Course Outcomes (COs) towards a PO is evaluated using descriptors such as High, Medium, Low, etc.

Observations:

1. The first five Program Outcomes (POs) are purely technical in nature, while the other POs are non-technical.
2. For theory courses, while writing the Course Outcomes (COs), you need to restrict yourself between Bloom's Level 1 to Level 4. However, if it is a programming

course, restrict yourself between Bloom's Level 1 to Level 3, but for other courses, you can go up to Bloom's Level 4.

3. For laboratory courses, while composing COs, you need to restrict yourself between Bloom's Level 1 to Level 5.
4. Only for mini-projects and main projects, you may extend up to Bloom's Level 6 while composing COs.
5. For a given course, the course in-charge must involve all other professors who teach that course and ask them to come up with the CO-PO mapping. The course in-charge must take the average value of all these CO-PO mappings and finalize the values. Alternatively, the course in-charge can proceed with what the majority of faculty members prefer. Ensure that none of the professors handling the course discuss with each other while marking the CO-PO values.
6. If you want to match your COs with non-technical POs, correlate the action verbs used in the COs with the thumb rule given in the table and map the values. (This applies only for mapping COs to non-technical POs).

### 8.7. Tips for Assigning the values while mapping COs to PO s.

1. Select action verbs for a Course Outcome (CO) from different Bloom's levels based on the importance of the particular CO for the given course.
2. Stick to a single action verb while composing COs, but you may use multiple action verbs if the need arises.
3. You need to justify the marking of values in the CO-PO articulation matrix. Use a combination of words found in the COs, POs, and your course syllabus for writing the justification. Restrict yourself to one or two lines.
4. Values for the CO-PO (technical POs in particular) matrix can be assigned by:
  - (a) Judging the importance of the particular CO in relation to the PO s. If the CO matches strongly with a particular PO criterion, assign 3; if it matches moderately, assign 2; if the match is low, assign 1; otherwise, mark with a "-" symbol.
  - (b) If an action verb used in a CO appears at multiple Bloom's levels, then you need to judge which Bloom's level is the best fit for that action verb.

### 8.8. Method for Articulation

1. Identify the key competencies of POs/PSOs for each CO and create a corresponding mapping table by assigning marks in the corresponding cell. One important observation is that the first five POs are purely technical in nature, while the other POs are non-technical.
2. Justify each CO-PO/PSO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that match the given

Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs/PSOs, and your course syllabus for writing the justification.

3. Create a table listing the number of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Create a table displaying the percentage of key competencies for CO-PO/PSO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, prepare a Course Articulation Matrix (CO-PO/PSO Mapping) with COs and POs and COs and PSOs on a scale of 0 to 3, where:
  - 0 = No correlation (marked as “-”)
  - 1 = Low/slight correlation
  - 2 = Medium/moderate correlation
  - 3 = Substantial/high correlation

The correlation is based on the following strategy:

Range (C%)	Correlation Level
$0 \leq C \leq 10\%$	No correlation (0)
$10\% < C < 40\%$	Low/Slight correlation (1)
$40\% \leq C < 60\%$	Moderate correlation (2)
$60\% \leq C \leq 100\%$	Substantial/High correlation (3)

## 9. Key Competencies for Assessing Program Outcomes:

PO No.	NBA Statement / Vital Features	Key Components	No. of Key Components
PO1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems ( <b>Engineering Knowledge</b> ).	<ol style="list-style-type: none"> <li>1. <b>Scientific Principles:</b> Application of scientific principles and methodologies.</li> <li>2. <b>Mathematical Principles:</b> Utilization of mathematical concepts in problem-solving.</li> <li>3. <b>Interdisciplinary Integration:</b> Integration of knowledge from various engineering disciplines.</li> <li>4. <b>Engineering Specialization:</b> Application of specialized engineering knowledge in complex engineering problems.</li> </ol>	4

<p><b>PO2</b></p>	<p>Identify, formulate, review research literature, and analyze complex engineering problems, reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences <b>(Problem Analysis).</b></p>	<ol style="list-style-type: none"> <li>1. <b>Identity:</b> Recognizing and defining complex engineering problems or opportunities.</li> <li>2. <b>Formulate:</b> Structuring and abstracting the problem for systematic analysis.</li> <li>3. <b>Review:</b> Examining research literature</li> <li>4. <b>Analyze:</b> Investigating problems using data collection and relevant methodologies.</li> <li>5. <b>First Principles:</b> Applying mathematical, natural, and engineering sciences in problem- solving.</li> <li>6. <b>Substantiated Conclusions:</b> Ensuring accuracy and reliability through validation.</li> <li>7. <b>Experimental Design:</b> Planning and conducting experiments for problem analysis.</li> <li>8. <b>Solution Development:</b> Implementing and testing solutions through experimentation.</li> <li>9. <b>Interpretation:</b> Evaluating results to draw meaningful engineering conclusions.</li> <li>10. <b>Documentation:</b> Recording findings systematically for future reference and learning.</li> </ol>	<p><b>10</b></p>
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<p><b>PO3</b></p>	<p>Design solutions for complex Engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and Environmental considerations (Design/Development of Solutions).</p>	<ol style="list-style-type: none"> <li>1. <b>Design:</b> Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations.</li> <li>2. <b>Solutions:</b> Understand customer and user needs while considering factors such as aesthetics.</li> <li>3. <b>System Components:</b> Identify and manage cost drivers in engineering solutions.</li> <li>4. <b>Processes:</b> Use creativity to develop innovative engineering solutions.</li> <li>5. <b>Specified Needs:</b> Ensure fitness for purpose across production, operation, maintenance, and disposal.</li> <li>6. <b>Public Health &amp; Safety:</b> Manage the design process and evaluate outcomes for safety and risk assessment.</li> <li>7. <b>Cultural Considerations:</b> Understand the commercial and economic context of engineering processes.</li> <li>8. <b>Societal Considerations:</b> Apply management techniques to achieve engineering objectives in a broader context.</li> <li>9. <b>Environmental Considerations:</b> Promote sustainable development through engineering activities.</li> <li>10. <b>Appropriate Considerations:</b> Be aware of legal frameworks governing engineering activities, including personnel, health, safety, and environmental risks.</li> </ol>	<p><b>10</b></p>
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<p style="text-align: center;"><b>PO4</b></p>	<p>Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions <b>(Conduct Investigations of Complex Problems).</b></p>	<ol style="list-style-type: none"> <li>1. <b>Research-Based Knowledge:</b> Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively.</li> <li>2. <b>Research Methods:</b> Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data.</li> <li>3. <b>Design of Experiments:</b> Address complex problems in various engineering contexts, including operations, management, and technology development.</li> <li>4. <b>Analysis:</b> Leverage technical literature and reliable information sources.</li> <li>5. <b>Interpretation of Data:</b> Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data.</li> <li>6. <b>Synthesis:</b> Ensure high-quality results by integrating various data sources and considering quality control during engineering investigations.</li> <li>7. <b>Valid Conclusions:</b> Draw valid conclusions by addressing technical uncertainties through sound reasoning and scientific principles.</li> <li>8. <b>Engineering Principles:</b> Apply fundamental engineering principles to analyze and interpret key engineering processes and challenges.</li> <li>9. <b>Modelling Techniques:</b> Use analytical and modeling techniques to identify, classify, and describe the performance of engineering systems and components.</li> <li>10. <b>Quantitative Methods:</b> Employ analytical software and quantitative methods efficiently and accurately.</li> </ol>	<p style="text-align: center;"><b>10</b></p>
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<p><b>PO5</b></p>	<p>Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modeling to complex Engineering activities with an understanding of the limitations (<b>Modern Tool Usage</b>).</p>	<ol style="list-style-type: none"> <li>1. <b>Create:</b> Develop engineering solutions using modern tools across various disciplines.</li> <li>2. <b>Select:</b> Identify appropriate prediction and modeling tools for diverse engineering applications.</li> <li>3. <b>Apply:</b> Utilize IT tools in engineering analysis, design, and decision-making.</li> <li>4. <b>Techniques:</b> Implement simulation tools in different engineering fields.</li> </ol>	<p>4</p>
<p><b>PO6</b></p>	<p>Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice (<b>The Engineer and Society</b>).</p>	<ol style="list-style-type: none"> <li>1. <b>Contextual Knowledge:</b> Understand the commercial and economic context of engineering processes.</li> <li>2. <b>Management Techniques:</b> Apply management strategies in engineering objectives within this context.</li> <li>3. <b>Sustainable Development:</b> Promote sustainable development through engineering activities.</li> <li>4. <b>Legal Awareness:</b> Recognize relevant legal requirements governing engineering practices, including health, safety, and environmental risks.</li> <li>5. <b>Professional Ethics:</b> Uphold high standards of professional and ethical conduct in engineering.</li> </ol>	<p>5</p>

<p><b>PO7</b></p>	<p>Understand the impact of the professional Engineering solutions in societal and Environmental contexts, and demonstrate the knowledge of, and need for sustainable development (Environment and Sustainability).</p>	<ol style="list-style-type: none"> <li>1. <b>Socio-Economic Impact:</b> Understand the socio-economic effects of engineering solutions on society.</li> <li>2. <b>Political Impact:</b> Recognize the political implications and responsibilities of engineering solutions.</li> <li>3. <b>Environmental Impact:</b> Assess the environmental consequences of engineering practices and solutions.</li> <li>4. <b>Sustainability:</b> Demonstrate the importance of sustainable development in engineering solutions.</li> </ol>	<p>4</p>
<p><b>PO8</b></p>	<p>Apply ethical principles and commit to professional ethics and responsibilities and norms of the Engineering practice (Ethics).</p>	<ol style="list-style-type: none"> <li>1. <b>Ethical Judgement:</b> Make informed decisions based on ethical principles, using professional codes of ethics to guide actions and evaluate the ethical aspects of practice.</li> <li>2. <b>Integrity:</b> Demonstrate a strong sense of trust and integrity, standing firm in one's values while acting responsibly and ethically.</li> <li>3. <b>Fairness and Equity:</b> Ensure fair treatment and equity in all professional activities, valuing diversity and respecting others' perspectives.</li> <li>4. <b>Professional Responsibility:</b> Adhere to the norms of engineering practice by committing to high ethical standards and demonstrating ethical behavior in all professional engagements.</li> </ol>	<p>4</p>

<p><b>PO9</b></p>	<p>Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings <b>(Individual and Teamwork)</b>.</p>	<ol style="list-style-type: none"> <li>1. <b>Independence:</b> Work effectively as an individual, taking ownership of tasks and driving progress independently.</li> <li>2. <b>Maturity:</b> Demonstrate maturity by focusing on goal achievement, requiring minimal external motivation.</li> <li>3. <b>Self-Direction:</b> Approach vaguely defined problems with systematic problem-solving skills to find solutions.</li> <li>4. <b>Team Collaboration:</b> Engage in teamwork during various activities, including hands-on labs and multidisciplinary projects.</li> <li>5. <b>Adaptability:</b> Participate in diverse team settings, adjusting to different roles and projects such as mini projects and design tasks.</li> <li>6. <b>Project Management:</b> Understand and apply principles of teamwork and project management to effectively complete assignments and projects.</li> <li>7. <b>Peer Evaluation:</b> Contribute to team dynamics by evaluating and reflecting on individual and group performance.</li> <li>8. <b>Building Relationships:</b> Foster teamwork and lasting relationships, contributing to both academic success and post-graduation professional networks.</li> <li>9. <b>Organizational Integration:</b> Collaborate with individuals across all levels of an organization, demonstrating adaptability and interpersonal skills.</li> <li>10. <b>Effective Communication:</b> Develop strong relationships through positive interactions, showcasing an ability to get along with others and work cohesively in teams.</li> </ol>	<p><b>10</b></p>
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<p><b>PO10</b></p>	<p>Communicate effectively on complex Engineering activities with the Engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions <b>(Communication).</b></p>	<ol style="list-style-type: none"> <li>1. <b>Clarity:</b> Communicate complex engineering concepts clearly and concisely in written reports and design documentation.</li> <li>2. <b>Grammar and Punctuation:</b> Ensure high standards of grammar and punctuation in written communication, maintaining professionalism and clarity.</li> <li>3. <b>References:</b> Properly reference sources in written communication, ensuring accuracy and academic integrity.</li> <li>4. <b>Speaking Style:</b> Deliver oral presentations effectively, with appropriate speaking style to engage the audience and convey technical information clearly.</li> <li>5. <b>Subject Matter:</b> Demonstrate a deep understanding of the subject matter, clearly communicating complex ideas during oral discussions and presentations.</li> </ol>	<p>5</p>
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<p><b>PO11</b></p>	<p>Demonstrate knowledge and understanding of the Engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multi-disciplinary Environments (<b>Project Management and Finance</b>).</p>	<ol style="list-style-type: none"> <li>1. <b>Scope Definition:</b> Define the project scope clearly to ensure alignment with objectives and requirements.</li> <li>2. <b>Critical Success Factors:</b> Identify and prioritize critical success factors necessary for project completion and success.</li> <li>3. <b>Deliverables:</b> Ensure the timely delivery of project outputs, meeting the predefined objectives and quality standards.</li> <li>4. <b>Work Breakdown Structure:</b> Develop and organize a structured breakdown of tasks and activities to achieve project goals.</li> <li>5. <b>Scheduling:</b> Create and manage schedules to ensure tasks are completed on time and milestones are met.</li> <li>6. <b>Budget Management:</b> Develop and manage project budgets, ensuring that resources are used efficiently and within financial constraints.</li> <li>7. <b>Quality Assurance:</b> Apply quality control measures to ensure that project deliverables meet the required standards.</li> <li>8. <b>Human Resources Planning:</b> Plan and allocate human resources effectively, ensuring the right skills and team dynamics.</li> <li>9. <b>Stakeholder Management:</b> Identify and manage stakeholders, ensuring their needs and expectations are addressed throughout the project.</li> <li>10. <b>Risk Management:</b> Develop a risk register and apply strategies to identify, assess, and mitigate project risks.</li> </ol>	<p><b>10</b></p>
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<p><b>PO12</b></p>	<p>Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change <b>(Life - Long Learning)</b>.</p>	<ol style="list-style-type: none"> <li>1. <b>Professional Certificate:</b> Pursue professional, Academic, Global certifications.</li> <li>2. <b>Advanced Education:</b> Begin and work towards advanced programs to further deepen knowledge.</li> <li>3. <b>Continuous Learning:</b> Stay updated on industry trends and emerging technologies to remain relevant in the field.</li> <li>4. <b>Skill Acquisition:</b> Learn at least 2–3 new significant skills annually to ensure continuous growth and development.</li> <li>5. <b>Training Commitment:</b> Dedicate time for formal training for a standard duration of training each year.</li> <li>6. <b>Personal Development:</b> Engage in ongoing self-improvement efforts to enhance both personal and professional growth.</li> <li>7. <b>Adaptability:</b> Be adaptable to technological changes by actively pursuing new learning opportunities and challenges.</li> <li>8. <b>Networking:</b> Build a network with industry peers and professionals to stay informed and grow knowledge through collaboration</li> </ol>	<p><b>8</b></p>
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## 10. Key Competencies for Assessing Program Specific Outcomes:

PSO	NBA statement/Vital features	No. of vital features
<b>PSO1</b>	<p>Understand, analyse, apply, design and develop engineering systems adopting thermal, design and manufacturing concepts.</p> <ol style="list-style-type: none"> <li>1. Fundamental Engineering Knowledge.</li> <li>2. Design and Development Skills.</li> <li>3. Manufacturing and Production Knowledge.</li> </ol>	3
<b>PSO2</b>	<p>Utilize computational and design tools for efficient product development in addressing industrial challenges.</p> <ol style="list-style-type: none"> <li>1. Product Development.</li> <li>2. Industrial challenges.</li> <li>3. Design Tools.</li> <li>4. Computational Tools.</li> <li>5. Utilize computational and design tools.</li> </ol>	5
<b>PSO3</b>	<p>Make use of acquired knowledge and entrepreneurial skills to create innovative solutions that address societal needs while promoting sustainable growth.</p> <ol style="list-style-type: none"> <li>1. Entrepreneurial skills.</li> <li>2. Innovative solutions.</li> <li>3. Societal needs.</li> <li>4. Sustainable growth.</li> </ol>	4

## 11. Program Outcomes and Program Specific outcomes Attained through course modules:

Courses offered in Computer Science and Engineering Curriculum (MLRS-R22) and POs/PSOs attained through course modules for I, II, III, IV, V, VI, VII and VIII semesters.

CODE	SUBJECT	PO												PSO			
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	
<b>IB. Tech – I Semester</b>																	
2410001	Matrices and Calculus	✓	✓	✓	✓										✓	✓	
2410008	Applied Physics	✓	✓			✓	✓										
2410501	Problem Solving Using C and C++	✓	✓	✓	✓										✓	✓	✓
2410010	English for Skill Enhancement							✓	✓	✓	✓	✓			✓	✓	
2410372	Engineering Workshop	✓	✓	✓	✓										✓		
2410071	Applied Physics Laboratory	✓	✓	✓	✓										✓	✓	✓
2410571	Problem Solving Using C and C++ Lab	✓	✓	✓	✓										✓		
2410073	English Language and Communication Skills Lab							✓	✓	✓	✓	✓	✓				
2410596	Web Application Development	✓	✓	✓		✓										✓	
2410FL2	Foreign Language							✓	✓	✓	✓	✓	✓				
CODE	SUBJECT	PO												PSO			
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	
<b>IB. Tech – II Semester</b>																	
2420002	Differential Equations and Vector Calculus	✓	✓	✓	✓		✓								✓	✓	✓
2420009	Engineering Chemistry	✓	✓		✓		✓								✓		
2420321	Applied Mechanics	✓	✓	✓	✓										✓	✓	✓
2420502	Essentials of Problem-Solving using Python					✓	✓	✓	✓						✓	✓	✓
2420371	Computer Aided Engineering Graphics	✓	✓	✓	✓										✓	✓	✓

2420072	Engineering Chemistry Laboratory	✓	✓	✓	✓	✓									✓	✓	✓
2420373	Fuels & lubricants Laboratory	✓	✓	✓	✓	✓									✓	✓	✓
2420572	Essentials of Problem-Solving using Python Laboratory	✓	✓	✓	✓	✓									✓	✓	✓
2420027	Public speaking skills						✓	✓	✓	✓	✓	✓	✓				
2420026	Yoga & Inner Engineering								✓					✓			
CODE	SUBJECT	PO												PSO			
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	
<b>IIB. Tech – I Semester</b>																	
2430322	Mechanics of Solids	✓	✓	✓	✓	✓									✓	✓	
2430323	Metallurgy and Material Science	✓	✓	✓	✓	✓									✓	✓	✓
2430324	Thermodynamics	✓	✓	✓	✓	✓		✓								✓	
2430507	Data Structures	✓	✓	✓	✓										✓	✓	✓
2430007	Probability, Statistics and Numerical Methods	✓	✓	✓	✓				✓	✓					✓	✓	✓
243ExL1	Design and Innovation	✓	✓	✓	✓	✓									✓	✓	✓
2430374	Material Science & Mechanics of Solids Laboratory	✓	✓	✓	✓				✓							✓	
2430575	Data Structures Laboratory using Python	✓	✓	✓	✓	✓			✓							✓	✓
2430375	Computer Aided Machine Drawing Practice	✓	✓	✓	✓										✓		✓
2430391	Internship - I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2430395	Automotive Design Course - I						✓	✓	✓	✓						✓	✓
243IKS2	Indian Knowledge System						✓	✓	✓						✓	✓	
CODE	SUBJECT	PO												PSO			
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	
<b>IIB. Tech – II Semester</b>																	
2440202	Basic Electrical and Electronic Engineering	✓	✓	✓	✓		✓		✓	✓					✓	✓	

2440325	Manufacturing Process	✓	✓	✓	✓		✓								✓	✓
2440326	Theory of Machines	✓	✓	✓	✓									✓	✓	
2440327	Thermal Engineering - I	✓	✓	✓	✓				✓	✓				✓	✓	
2440328	Mechanics of Fluids and Hydraulic Machinery	✓	✓	✓	✓	✓			✓	✓				✓	✓	✓
244EXL2	Prototype / Model Development and Entrepreneurship	✓	✓	✓	✓				✓	✓				✓		✓
2440376	Mechanics of Fluids and Hydraulic Machinery Laboratory	✓	✓	✓	✓				✓	✓				✓	✓	✓
2440377	Manufacturing Process Laboratory	✓	✓	✓	✓	✓			✓	✓				✓	✓	✓
2440272	Basic Electrical and Electronic Engineering Laboratory	✓	✓	✓	✓				✓	✓					✓	✓
2430396	Automotive Design Course - II						✓	✓	✓	✓				✓		✓
2440021	Environmental Science						✓	✓	✓						✓	
CODE	SUBJECT	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
<b>III B. Tech – I Semester</b>																
2450329	Design of Machine Elements	✓	✓	✓	✓				✓	✓				✓		✓
2450330	Metrology and Machine Tools	✓	✓	✓	✓				✓	✓					✓	
2450331	Thermal Engineering - II	✓	✓	✓	✓		✓		✓	✓					✓	✓
2450101	Air and Noise Pollution Control	✓	✓	✓	✓	✓			✓	✓					✓	✓
2450342	Non-Destructive Testing	✓	✓	✓	✓				✓	✓					✓	
2450378	Metrology and Machine Tools Laboratory	✓	✓	✓	✓	✓			✓	✓				✓		
2450379	Theory of Machines Laboratory	✓	✓	✓										✓	✓	
2450380	Thermal Engineering	✓	✓	✓	✓	✓			✓						✓	✓

	Laboratory																	
2450387	Field Based Project	✓	✓	✓	✓	✓			✓	✓						✓	✓	
2450022	Gender Sensitization						✓	✓	✓	✓								
CODE	SUBJECT	PO												PSO				
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3		
<b>III B. Tech – II Semester</b>																		
2460332	Design of Transmission Systems						✓	✓	✓	✓						✓		
2460333	Heat Transfer	✓	✓	✓	✓										✓	✓	✓	
2460334	Finite Element Analysis	✓	✓	✓	✓				✓	✓						✓	✓	
2460102	Remote Sensing & GIS	✓	✓	✓	✓		✓		✓						✓	✓	✓	
2460345	Non-Traditional Machining Process						✓	✓	✓	✓		✓			✓			
2460381	Heat Transfer Laboratory	✓	✓	✓	✓		✓			✓						✓	✓	
2460382	Computer Aided Engineering Laboratory	✓	✓	✓	✓		✓		✓							✓	✓	
2460383	Computer Aided Production Drawing Practice Laboratory	✓	✓	✓	✓	✓										✓		
2460025	Human Values and Professional Ethics						✓	✓	✓	✓								
CODE	SUBJECT	PO												PSO				
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3		
<b>IV B. Tech – I Semester</b>																		
2470335	Instrumentation and Control Systems	✓	✓	✓	✓											✓	✓	✓
2470336	CAD/CAM	✓	✓	✓	✓	✓			✓	✓							✓	✓
2480010	Business Economics and Financial Analysis	✓	✓	✓	✓				✓	✓							✓	✓
2470103	Disaster Management	✓	✓		✓												✓	✓
2470349	Refrigeration and Air Conditioner						✓	✓	✓									
2470354	Robotics	✓	✓	✓	✓		✓		✓								✓	✓

2470384	CAD/CAM Laboratory						✓	✓	✓	✓				✓		
2470385	Instrumentation and Control Systems Laboratory	✓	✓	✓	✓									✓	✓	✓
2470392	Internship - II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2470388	Project Stage - I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2470023	Constitution of India					✓	✓	✓	✓	✓			✓			
CODE	SUBJECT	PO												PSO		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
<b>IV B. Tech – II Semester</b>																
2480357	Total quality management	✓	✓	✓	✓		✓								✓	
2480364	Industrial Management				✓	✓	✓		✓	✓	✓		✓	✓		
2480389	Technical Seminar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2480390	Project Stage-II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

## 12. Methods for measuring Learning Outcomes and Value Addition:

There are many different ways to assess student learning. In this section, we present the different types of assessment approaches available and the different frame works to interpret the results.

- I. Continuous Internal Assessment (CIA).
- II. Comprehensive Assessment Tool (CAT)
- III. Semester end examination (SEE)
- IV. Laboratory and project work
- V. Course end survey
- VI. Program exit survey
- VII. Alumni survey
- VIII. Employer survey
- IX. Course expert committee
- X. Department Advisory Board
- XI. Faculty meetings
- XII. Professional Societies

**The above assessment indicators are detailed below.**

### 12.1. Continuous Internal Assessment (CIA)

The framework for Continuous Internal Assessment (CIA) for the Undergraduate (UG) courses includes Continuous Internal Examinations (CIEs), quiz and CAT (includes PPT, poster presentation etc). All these are mandatory and designed in a systematic way to assess the understanding of concepts, analytical and problem-solving skills, communication skills, and overall subject competency in accordance with the principles of Outcome-Based Education (OBE).

The assessment performance is formally evaluated to ensure consistency, transparency, and achievement of Course Outcomes (COs) and Program Outcomes (POs). Constructive feedback is given to the students to enable continuous improvement and improve the teaching-learning process, thereby improving overall performance and achievement of outcomes.

### 12.2. Comprehensive Assessment Tool (CAT)

The Comprehensive Assessment Tool (CAT) is a flexible, outcome-driven evaluation mechanism that enhances faculty autonomy by enabling the design of innovative and diverse pedagogical practices beyond conventional examinations. It encompasses a broad range of activities including certifications from open coding platforms, Tech Talks, term papers, MOOCs, open-ended experiments, concept videos, hackathons, and language proficiency tests. Through the CAT, the classroom is transformed into an effective learning centre where assessment is continuous, comprehensive, and aligned with defined Course Outcomes (COs) and Program Outcomes (POs). This tool fosters holistic student development by integrating technical proficiency, critical thinking, and professional communication into a unified and measurable assessment framework.

### 12.3. Semester End Examination (SEE)

The semester end examination is conducted for all the courses in the department. Before the Semester end examinations course reviews are conducted, feedback taken from students and remedial measures will be taken up such that the student gets benefited before going for end exams. The positive and negative comments made by the students about the course are recorded

and submitted to the departmental academic council and to the principal for taking necessary actions to better the course for subsequent semesters.

#### 12.4. Laboratory and Project Works

The laboratory work is continuously monitored and assessed to suit the present demands of the industry. Students are advised and guided to do project works giving solutions to research/ industrial problems to the extent possible by the capabilities and limitations of the student. The results of the assessment of the individual projects and laboratory work can easily be conflated in order to provide the students with periodic reviews of their overall progress and to produce terminal marks and grading.

#### 12.5. Course Exit Surveys

Students are encouraged to fill-out a brief survey on the fulfillment of course objectives. The data is reviewed by the concerned course faculty and the results are kept open for the entire faculty. Based on this, alterations or changes to the course objectives are undertaken by thorough discussions in faculty and meetings.

#### 12.6. Programme Exit Survey

The Program Exit Questionnaire is to be completed by all students leaving the institution. The questionnaire is designed to gather information from students regarding program educational objectives, overall program experiences, career choices, and any suggestions or comments for program improvement. The opinions expressed in the exit interview forms are reviewed by the Department Advisory Board (DAB) for potential implementation.

#### 12.7. Alumni Survey

The survey gathers insights from former students of the department regarding their employment status, further education, perceptions of institutional emphasis, estimated gains in knowledge and skills, undergraduate involvement, and continued engagement with Marri Laxman Reddy Institute of Technology and Management. This survey is conducted every year, and the collected data is analyzed for continuous improvement.

#### 12.8. Employer Survey

The main purpose of this employer questionnaire is to know employer's views about the skills they require of employees compared to the skills actually possessed by them. The purpose is also to identify gaps in technical and vocational skills, determine the need for required training practices to fill these gaps, and establish criteria for hiring new employees. These employer surveys are reviewed by the College Academic Council (CAC) to modify the present curriculum to suit the requirements of the employer.

#### 12.9. Course Expert Committee

The course expert team is responsible in exercising the central domain of expertise in developing and renewing the curriculum and assessing its quality and effectiveness to the highest of professional standards. Inform the Academic Committee the 'day-to-day' matters as are relevant to the offered courses. This committee will consider the student and staff feedback on the efficient and effective development of the relevant courses. The committee also reviews the course full stack content developed by the respective course coordinator.

### 12.10. Department Advisory Board

The Departmental Advisory Board (DAB) plays an important role in the development of the department. The department-level Advisory Board is established to provide guidance and direction for the qualitative growth of the department. The board interacts and maintains liaison with key stakeholders.

The DAB will monitor the progress of the program and develop or recommend new or revised goals and objectives for the program. Additionally, the DAB will review and analyse the gaps between the curriculum and industry requirements, providing necessary feedback or advice to improve the curriculum

### 12.11. Faculty Meetings

The DAB meets bi-annually for every academic year to review the strategic planning and modification of PEOs. Faculty meetings are conducted at least once in a month for ensuring the implementation of PAQIC's suggestions and guidelines. All these proceedings are recorded and kept for the availability of all faculties.

### 12.12. Professional Societies

The importance of professional societies like TASK (Telangana Academy of Skill and Knowledge), Society for Automotive Engineers (SAE), Confederation of Indian Industry (CII), ICT Academy and the American Society for Mechanical Engineers (ASME). These professional bodies function as structured co-curricular platforms within the college, organizing technical talks, workshops, seminars, and industry interaction sessions to enhance students' technical competence and professional awareness. Regular activities conducted under TASK, SAE, CII, ICT Academy and ASME facilitate knowledge dissemination in hands-on training, workshops, distinguished lectures, and competitions, which help them develop problem-solving skills and address complex engineering challenges. Student and faculty chapters of the above societies are constituted for a better technical and entrepreneurial environment. These professional societies promote excellence in instruction, research, public service and practice.

## 13. CO-Assessment processes and tools:

Course outcomes are evaluated based on two approaches namely direct and indirect assessment methods. The direct assessment methods are based on the Continuous Internal Assessment (CIA) and Semester End Examination (SEE) whereas the indirect assessment methods are based on the course end survey and program exit survey provided by the students, Alumni and Employer.

The weightage in CO attainment of Direct and Indirect assessments are illustrated in Table.

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessment (CIE, Assignment & PPT/Poster Presentation/Viva-Voce/Case Study)	80%
	Semester End Examination	

Indirect Assessment	Course End Survey	20%
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### 13.1. Direct Assessment:

Direct assessment methods are based on the student's knowledge and performance in various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill. Additionally, they demonstrate that the student's work exhibits specific qualities such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of the delivery of course content is listed in the table.

- Continuous internal examination, semester end examinations, Assignment, CAT (includes PPT, poster presentation etc) are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the PO s.
- Performance in Assignment is indicative of the student's communication skills.

S. No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core/ Elective	Continuous Internal Assessment	Twice in a semester	30	Answer script
		Assignment	One Assignment per unit.	5	Assignment
		CAT(Tech-talk, Concept video, NPTEL certificate etc)	Twice in a semester	5	PPT, Poster Presentation etc
		Semester End Examination	Once in a semester	60	Answer script
2	Laboratory	Day-to-Day Evaluation	Once in a week	10	Work sheets
		Viva-Voce	Once in a week	10	Work sheets
		Certificate/ Open ended experiment	Once in a semester	10	Certificate/ Work sheet
		Internal laboratory assessment	Twice in a semester	10	Answer script
		Semester End Examination	Once in a semester	60	Answer script
3	Project Work	Presentation	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Thesis report
4	Technical Seminar	Presentation	Twice in a semester	100	Seminar report

### 13.2. Indirect Assessment:

Course End Survey-In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table.

TABLE 15: Tools used in In-direct assessment

Tools	Process	Frequency
Course end survey	<ul style="list-style-type: none"> <li>• Taken for every course at the end of the semester</li> <li>• Gives an overall view that helps to assess the extent of coverage/ compliance of Cos</li> <li>• Helps the faculty to improve upon the various teaching methodologies</li> </ul>	Once in a semester

**Direct Tools:** (Measurable in terms of marks and w.r.t.CO) Assessment done by faculty at department level.

**Indirect Tools:** (Non measurable (surveys) in terms of marks and w.r.t.CO) Assessment done at institute level.

## 14. PO/PSO-Assessment tools and Processes

The institute has the following methods for assessing the attainment of POs/PSOs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO/PSO based upon the mapping done.

TABLE 16: Attainment of PO / PSOs

	Assessment	Tools	Weight
<b>POs/PSOs Attainment</b>	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Student exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses, with appropriate weightage as per CO- PO mapping, as per the Program Articulation Matrix, are considered for the calculation of direct attainment of PO/PSOs.

### 14.1 PO Direct Attainment is calculated using the following rubric:

PO Direct Attainment = (Strength of CO-PO) \* CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

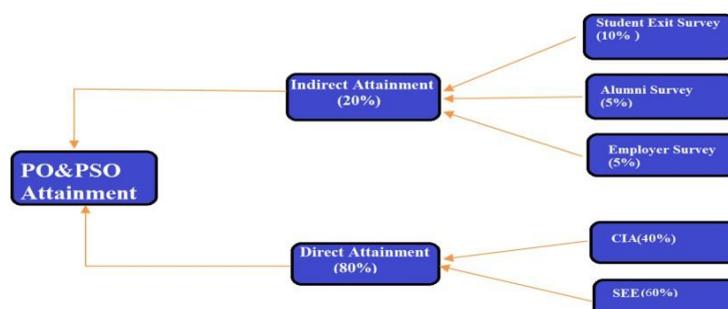


FIGURE 4: Evaluation process of POs / PSOs attainment

## 15. Course Descriptor:

The “Course Descriptor” provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for reference. The “Course Descriptor” contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Course Objectives
- Course Outcomes
- Content Delivery / Instructional Methodologies
- Syllabus
- List of Textbooks / References / Websites
- Evaluation Methodology
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are Assessed
- How Program Specific Outcomes are Assessed
- Mapping of each CO with PO(s), PSO(s)
- Justification for CO–PO/PSO Mapping - Direct
- Total Count of Key Competencies for CO–PO/PSO Mapping
- Percentage of Key Competencies for CO–PO/PSO
- Course Articulation Matrix (PO/PSO Mapping)
- Assessment Methodology - Direct
- Assessment Methodology – Indirect
- Mapping with Sustainability development goal



**MECHANICAL ENGINEERING**

1	Department	MECHANICAL ENGINEERING							
2	Course Name	THERMAL ENGINEERING-I							
3	Course Code	2440327							
4	Year/Semester	II/II							
5	Regulation	MLRS-R24							
7	Structure of the course	Theory				Practical			
		Lecture	Tutorials	Practical	Credit	L	T	P	C
		3	0	0	3	0	0	0	0
8	Type of course	BS	HS	ES	PC	PE	OE	PS	MC
		×	×	×	✓	×	×	×	×
9	Course Offered	Odd Semester		×	Even Semester			✓	
10	Total lecture, tutorial and practical hours for this course Offered (16 weeks of teaching per semester)								
	Lectures: 48 Hours		Tutorials: 16 hours		Practical: 0 hours				
11	Course Coordinator	Dr.K.VEERA RAGHAVULU							
12	Date Approved by BOS	15/07/2022							
13	Course Webpage	<a href="http://www.mlritm.ac.in/">www.mlritm.ac.in/</a>							
14	Prerequisites/	Level	Course Code	Semester	Prerequisites				
	Co-requisites	B.Tech	2430325	II-I	Thermodynamics				

**15. Course Overview:**

Thermal Engineering is a specialized course of Mechanical engineering and Chemical engineering with a focus on energy transformation. In this course students learn about the working and performance analysis of Engines, steam turbines, steam nozzles and gas turbines. A brief introduction to jet engines and rocket engines is also given. The concepts of thermal engineering play a crucial role in the operation of many equipment used for producing energy. Thus, understanding thermal engineering is essential for optimizing the processes to designing efficient systems.

**16. Course Objectives:**

The students will try to learn:

- Comprehensive Understanding of IC Engine Components and Systems
- Combustion Process Analysis for Enhanced Performance and Emission Control:

- Performance Evaluation of IC Engine Components and Applications:
- Analysis of Various Compressor Types and Their Operating Principles:
- Understanding the Role of Gas Turbines in Power Generation:

### 17. Course Outcomes:

After successful completion of the course, students should be able to:

CO1	Elaborate the working principles of IC Engine systems and its classification. (L3)
CO2	Explore the combustion stages of SI and CI engines, and factors influence for better combustion. (L3)
CO3	Evaluate the testing and performance parameters of IC engines. (L5)
CO4	Explain the function and working principles of rotary, reciprocating, dynamic axial compressors. (L2)
CO5	Understand the need, properties, and applications of alternate fuels, evaluating their merits and demerits(L1).

### 18. Course Learning Outcome (CLOs):

Sno	Topic Name	CLO No	Course Learning Outcome	Course Outcome	Blooms Level
1	SI engines	CLO 1	Analyse the working principles, fuel systems, and performance characteristics of SI engines, including carburetors, fuel injection systems, and combustion processes	CO1	Analyze
2	CI engines	CLO 2	<i>Evaluate</i> the functioning of CI engines, focusing on fuel injection systems, combustion cycles, and performance parameters Properties.	CO1	Evaluate
3	Ignition system	CLO 3	Demonstrate an understanding of ignition systems in internal combustion engines, comparing conventional and advanced ignition methods for efficient engine operation	CO1	Understand
4	Combustion in SI engines	CLO 4	<i>Analyze</i> the normal and abnormal combustion phenomena in SI engines, considering flame speed, engine variables, pre-ignition, and knocking effects	CO2	Analyze
5	Combustion in	CLO	<i>Evaluate</i> the four stages of combustion in	CO2	Evaluate

	CI engines	5	CI engines, the delay period, diesel knock, and the influence of engine variables on combustion efficiency		
6	Knocking	CLO 6	<i>Explain</i> the causes, effects, and control methods of knocking in SI and CI engines, including fuel properties, additives, and combustion chamber design	CO2	Understand
7	Parameters of performance	CLO 7	<i>Apply</i> the concepts of engine performance by measuring parameters such as cylinder pressure, fuel consumption, air intake, exhaust gas composition, and brake power	CO3	Apply
8	Heat balance sheet and chart	CLO 8	<i>Analyze</i> the heat balance of an internal combustion engine using heat balance sheets and charts to evaluate energy distribution and efficiency.	CO3	Analyze
9	compressors and Blowers.	CLO 9	<i>Explain</i> the classification, working principles, and performance characteristics of compressors, blowers, and fans, including positive displacement and dynamic types	CO3	Understand
10	Rotary Compressor	CLO 10	<i>Explain</i> the mechanical details, working principles, and efficiency considerations of rotary compressors, including Roots blowers and vane-sealed compressors	CO4	Understand
11	Centrifugal compressors	CLO 11	<i>Analyze</i> the operation of centrifugal compressors, considering energy transfer, velocity and pressure variations, impeller blade design, losses, and performance factors	CO4	Analyze
12	Axial Flow Compressors	CLO 12	<i>Evaluate</i> the working principles and performance parameters of axial flow compressors, including velocity triangles, degree of reaction, isentropic efficiency, and pressure rise calculations	CO4	Evaluate
13	Alternative fuels	CLO	Explain the need for alternative fuels and	CO5	Understand

		13	their properties.		
14	Hybrid vehicles	CLO 14	Describe the working principles of hybrid, fuel cell, and solar-powered vehicles.	CO5	Understand
15	CNG	CLO 15	Analyze the advantages and disadvantages of CNG compared to conventional fuels..	CO5	Analyze

### 19. Employability Skills:

- Problem-Solving and Analytical Skills
- Technical Knowledge and Practical Application
- Effective Communication and Team Collaboration

Problem-solving and analytical skills enhance employability by enabling individuals to tackle complex challenges and find effective solutions, which are highly valued by employers. Technical knowledge and practical application ensure that employees can confidently apply their expertise to real-world tasks, increasing their value in the workplace. Additionally, effective communication and teamwork are critical for collaborating with colleagues, sharing ideas clearly, and contributing to a positive, productive work environment—all of which are essential for career success..

### 20. Content Delivery / Instructional Methodologies:

✓	 Power Point Presentation	✓	 Chalk & Talk	✓	 Assignments	✓	 MOOC
✓	 ALP	✓	 Seminars	×	 Mini Project	✓	 Videos

### 21. Evaluation Methodology:

The performance of a student in a course will be evaluated for 100 marks each, with 40 marks allotted for CIE (Continuous Internal Evaluation) and 60 marks for SEE (Semester End-Examination). In CIE, for theory subjects, during a semester, there shall be two mid-term examinations.

Each Mid-Term examination (30 Marks) consists of two parts

- i) **Part – A** for 10 marks (Short Answer Types),
- ii) **Part – B** for 20 marks (Descriptive answer Type) with a total duration of 1.5 hours as follows:

**Total 30 marks will be scale down 10 marks.**

**The sum of two midterm examinations shall be taken as the final marks for mid- term**

## examinations.

The semester end examinations (SEE), will be conducted for 60 marks consisting of two parts viz.i) **Part-A** for 10 marks, ii) **Part-B** for 50 marks.

- a. Part-A is a compulsory question which consists of ten sub-questions from all units carrying equal marks.
- b. Part-B consists of three questions (numbered from 2 to 6) carrying 10 marks each. Each of these questions is from each unit and may contain sub-questions. For each question there will be an “either” “or” choice, which means that there will be two questions from each unit and the student should answer either of the two questions.
- c. The duration of Semester End Examination is 3 hours.

Table 1: **Outline for Continues Internal Evaluation (CIE-I and CIE-II) and SEE**

Activities	CIE-I	CIE-II	Sum of CIE	SEE	Total Marks
Continues Internal Evaluation (CIE)	10 Marks	10 Marks	40 Marks	60 Marks	CIE + SEE
Assignment	5 Marks	5 Marks			
CAT ( Concept video/Tech-talk/certificate)	5 Marks	5 Marks			
<b>Total Marks</b>	<b>20 Marks</b>	<b>20 Marks</b>	<b>40 Marks</b>	<b>60 Marks</b>	<b>100 Marks</b>

## 22. Course content - Number of modules: Five:

MODULE 1	<b>I.C. Engines:</b> Classification - Working principles of Four & Two stroke engine, SI & CI engines, Valve and Port Timing Diagrams, Air – Standard, air-fuel and actual cycles - Engine systems – Carburetor and Fuel Injection Systems for SI engines, Fuel injection systems for CI engines, Ignition, Cooling and Lubrication system, Fuel properties and Combustion Stoichiometry.	No. of Lectures: 12
MODULE 2	<b>Combustion in SI &amp; CI Engines:</b> Normal Combustion and abnormal combustion in SI engines – Importance of flame speed and effect of engine variables – Abnormal combustion, pre-ignition and knocking in SI Engines – Fuel requirements and fuel rating, anti-knock additives – combustion chamber – requirements, types of SI engines. Four stages of combustion in CI engines – Delay period and its importance – Effect of engine variables – Diesel Knock– Need for air movement, suction, compression and combustion induced turbulence in Diesel engine – open and divided combustion chambers and fuel injection– Diesel fuel	No. of Lectures:10

	requirements and fuel rating	
MODULE 3	<p><b>Testing and Performance:</b> Parameters of performance - measurement of cylinder pressure, fuel consumption, air intake, exhaust gas composition, Brake power – Determination of frictional losses and indicated power – Performance test – Heat balance sheet and chart Classification of compressors – Fans, blowers and compressors – positive displacement and dynamic types – reciprocating and rotary types.</p> <p><b>Reciprocating Compressors:</b> Principle of operation, work required, Isothermal efficiency volumetric efficiency and effect of clearance volume, staged compression, under cooling, saving of work, minimum work condition for staged compression</p>	No. of Lectures: 10
MODULE 4	<p><b>Rotary Compressor (Positive displacement type):</b> Roots Blower, vane sealed compressor, mechanical details and principle of working – efficiency considerations. Dynamic Compressors: Centrifugal compressors: Mechanical details and principle of operation – velocity and pressure variation. Energy transfer-impeller blade shape-losses, slip factor, power input factor, pressure coefficient and adiabatic coefficient – velocity diagrams – power. Axial Flow Compressors: Mechanical details and principle of operation – velocity triangles and energy transfer per stage degree of reaction, work done factor - isentropic efficiency- pressure rise calculations – Polytropic efficiency</p>	No. of Lectures: 08
MODULE 5	<p><b>Need for alternate fuel:</b> Availability and properties of alternate fuels, LPG, hydrogen, ammonia, CNG and LNG, vegetable oils and biogas, merits and demerits of various alternate fuels,</p> <p><b>Electric, Hybrid, Fuel Cell And Solar Cars :</b> Concept of hybrid electric drive train, types, architecture of series and parallel hybrid electric drive train, merits and demerits, high energy and power density batteries, fuel cell vehicles, solar powered vehicles – Working operations</p>	No. of Lectures:08

### TEXTBOOKS:

1. I.C. Engines, V. Ganesan, 4<sup>th</sup> Edition, Mc Graw Hill
2. Thermal Engineering, Mahesh M Rathore, 2<sup>nd</sup> Edition Tata Mc Graw Hill, 2010

### REFERENCE BOOKS:

1. Applied Thermodynamics for Engineering Technologists, Eastop & McConkey, Pearson 5<sup>th</sup> edition
2. Fundamentals of Classical Thermodynamics, Van Wylen G.J., Sonntag R.E., Wiley Eastern. 6<sup>th</sup> edition

### ELECTRONIC RESOURCES:

1. <https://www.youtube.com/watch?v=sO2OKC5j2II>
2. <https://archive.nptel.ac.in/courses/112/103/112103262/>
3. [https://onlinecourses.nptel.ac.in/noc22\\_me65/preview](https://onlinecourses.nptel.ac.in/noc22_me65/preview)
4. <https://nptel.ac.in/courses/112103262>

### 23. COURSE PLAN:

S. No	Topics to be covered	Cos	Reference
1.	Introduction	-	-
2.	Classification of IC engines	CO1	T2:2.3
3.	Working of Four stroke SI & CI engine	CO1	R1:2.6
4.	Working of Two stroke SI & CI engine	CO1	T1:2.6
5.	Actual cycles and their analysis of fuels	CO1	T2:2.7 R1:2.18
6.	Valve timing diagrams & Port timing diagrams	CO1	T2:2.22
7.	Engine systems- Fuel injection system for SI engines	CO1	T2:2.25
8.	Carburettor and types	CO1	T2:2.26 R1:2.55
9.	Fuel injection system for CI engines	CO1	T2:2.16 R1:2.61
10.	Ignition System	CO1	T2:2.30 R1:2.58
11.	Cooling system -Types	CO1	T2:3.6 R1:4.29
12.	Lubrication system	CO1	T2:3.14 R1:4.31
13.	Stages of combustion in SI engine -Normal combustion	CO2	T2:3.14 R1:4.33
14.	Importance of flame speed and engine variables	CO2	R1:4.36
15.	Pre ignition and Knocking in SI engines	CO2	T2:3.18 R1:4.64
16.	Fuel requirement and rating	CO2	T2:3.22
17.	Combustion chambers in SI engines	CO2	T2:4.2
18.	Stages of combustion in CI engines	CO2	T1:4.12 R2:5.75
19.	Delay period and importance of flame speed on engine variables	CO2	T1:4.8 R1:5.72
20.	Diesel knock-air movement, suction, compression.	CO2	T1:5.8 R1:5.73
21.	Combustion chambers in diesel engines	CO2	T1:5.14 R1:6.78
22.	Parameters of performance,	CO2	T2:5.19 R1:6.81
23.	Indicated power	CO2	T1:6.4
24.	Brake power & determination of friction losses	CO2	T2:7.7 R1:7.74
25.	Heat balance sheet, Measurement of cylinder pressure	CO3	T1:7.12 R2:8.75

26.	Principle of operation of reciprocating compressor	CO3	T1:7.8 R1:8.72
27.	Isothermal efficiency volumetric efficiency and effect of clearance volume	CO3	T1:8.8 R1:8.73
28.	Compressor work calculation	CO3	T1:12.4 R2:13.68
29.	Saving of compressor work	CO3	T2:13.7 R1:14.74
30.	Minimum work condition for staged compression	CO3	T1:5.8 R1:5.73
31.	Working of various rotary compressors- Roots blower	CO4	T1:5.14 R1:6.78
32.	Vane sealed compressor	CO3	T2:5.19 R1:6.81
33.	Centrifugal compressors: Mechanical details and principle of operation	CO4	T1:6.4
34.	Velocity and pressure variation	CO4	T2:7.7 R1:7.74
35.	velocity diagrams	CO4	T1:7.12 R2:8.75
36.	velocity diagrams	CO4	T1:7.8 R1:8.72
37.	Axial Flow Compressors	CO4	T1:8.8 R1:8.73
38.	velocity triangles & degree of reaction	CO4	T1:12.4 R2:13.68
39.	Need of alternative fuel	CO4	T2:13.7 R1:14.74
40.	Availability and properties of alternative fuels	CO4	T1:5.8 R1:5.73
41.	LPG,	CO5	T1:5.14 R1:6.78
42.	Hydrogen and ammonia	CO5	T2:5.19 R1:6.81
43.	CNG,	CO5	T1:6.4
44.	LNG	CO5	T2:7.7 R1:7.74
45.	Vegetables oils and biogas	CO5	T1:7.12 R2:8.75
46.	Hybrid electric drive train & Types.	CO5	T1:7.12 R2:8.75
47.	Series and parallel hybrid electric drive train	CO5	T1:7.13 R2:8.75
48.	Solared powered vehicles,Active learning (Think pair shares)	CO5	T1:7.14 R2:8.75

#### 24. PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES:

<b>PO1:</b> Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and engg. specialization to the solution of complex engineering problems.
<b>PO2:</b> Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.
<b>PO 3:</b> Design/development of solutions: Design solutions for complex engineering

problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.
<b>PO4:</b> Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
<b>PO5:</b> Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
<b>PO6:</b> The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
<b>PO7:</b> Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
<b>PO 8:</b> Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
<b>PO 9:</b> Individual and team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.
<b>PO10:</b> Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.
<b>PO 11:</b> Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.
<b>PO 12:</b> Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
<b>Program Specific Outcomes</b>
<b>PSO1:</b> Understand, analyse, apply, design, and develop engineering systems adopting <b>thermal, design, and manufacturing concepts.</b>
<b>PSO2:</b> Utilize computational and design tools for efficient product development in addressing industrial challenges.
<b>PSO3:</b> Make use of acquired knowledge and entrepreneurial skills to create innovative solutions that address societal needs while promoting sustainable growth.

## 25. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes		Strength	Proficiency Assessed by
PO1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems	3	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
PO2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
PO3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	1	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
PO4	Conduct Investigations of Complex Problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	1	CIE/ PPT/ Objective / quiz /SEE/ Assignments/ Viva-Voce
PO 6	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	1	Assignments/ SEE /CIE, AAT, QUIZ
PO 12	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	1	CIE/Quiz/AAT

## 26. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Outcomes		Strength	Proficiency Assessed by
PSO1	Students acquire necessary technical skills in mechanical engineering that make them employable graduate.. <b>Technical and Engineering Skills &amp; Adaptability and Lifelong Learning</b>	3	CIE/ PPT/ SEE/ Objective / quiz / Assignments/ Viva-Voce

PSO2	An ability to impart technological inputs towards development of society by becoming an entrepreneur. <b>Innovation and Problem-Solving &amp; Entrepreneurial and Leadership Skills</b>	2	CIE/ PPT/ SEE/ Objective / quiz / Assignments/ Viva-Voce
PSO3	Make use of acquired knowledge and <b>entrepreneurial skills</b> to create <b>innovative solutions</b> that address <b>societal needs</b> while promoting <b>sustainable growth</b> .	1	CIE/ PPT/ SEE/ Objective / quiz / Assignments/ Viva-Voce

3 = High; 2 = Medium; 1 = Low

## 27. MAPPING OF EACH CO WITH PO(s), PSO(s):

CO	PROGRAM OUTCOMES												PSOs		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
TKC	4	10	10	10	4	5	4	4	10	5	10	8	4	4	4
CO1	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	✓	-	-	✓	-	-	-	-	-	-	✓	✓	-
CO3	✓	✓	-	✓	-	-	-	-	-	-	-	✓	✓	-	-
CO4	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	-	-	-	-	-	-	-	-	-	✓	✓	✓

Course Outcomes	PO'S/ PSO'S	Justification for mapping (Students will be able to)	No. of Key Competencies
CO1	PO1	1. Utilization of mathematical concepts in problem-solving. 2. Integration of knowledge from various engineering disciplines	2
	PO2	1. Structuring and abstracting the problem for systematic analysis 2. Examining research literature 3. Investigating problems using data collection and relevant methodologies 4. Planning and conducting experiments for problem analysis. 5. Implementing and testing solutions through experimentation.	5
CO2	PO3	1. Manage the design process and evaluate outcomes for safety and risk assessment.	2

		2. Apply management techniques to achieve engineering objectives in a broader context	
	PO6	<ol style="list-style-type: none"> <li>1. Understand the commercial and economic context of engineering processes.</li> <li>2. Apply management strategies in engineering objectives within this context.</li> <li>3. Promote sustainable development through engineering activities.</li> <li>4. Recognize relevant legal requirements governing engineering practices, including health, safety, and environmental risks.</li> </ol>	4
	PSO1	<ol style="list-style-type: none"> <li>1. Fundamental engineering knowledge</li> <li>2. Thermal engineering concepts</li> <li>3. Design and development skills</li> </ol>	3
	PSO2	<ol style="list-style-type: none"> <li>1. Product development</li> <li>2. Identification of industrial challenges</li> </ol>	2

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CO3	PO1	<ol style="list-style-type: none"> <li>1. Application of scientific principles and methodologies.</li> <li>2. Utilization of mathematical concepts in problem-solving.</li> </ol>	2
	PO2	<ol style="list-style-type: none"> <li>1. Structuring and abstracting the problem for systematic analysis.</li> <li>2. Examining research literature</li> <li>3. Investigating problems using data collection and relevant methodologies.</li> <li>4. Applying mathematical, natural, and engineering sciences in problem-solving.</li> </ol>	4
	PO4	<ol style="list-style-type: none"> <li>1. Gain a deep understanding of materials, equipment, processes, and products through research to address engineering problems effectively.</li> <li>2. Develop essential laboratory and workshop skills to carry out experimental investigations and gather reliable data.</li> <li>3. Address complex problems in various engineering contexts, including operations, management, and technology development.</li> <li>4. Leverage technical literature and reliable information sources</li> <li>5. Follow appropriate codes of practice and industry standards when analyzing and interpreting experimental data.</li> </ol>	5
	PSO1	<ol style="list-style-type: none"> <li>1. Fundamental engineering knowledge</li> <li>2. Thermal engineering concepts</li> <li>3. Design and development skills</li> </ol>	3
CO4	PO1	<ol style="list-style-type: none"> <li>1. Application of scientific principles and methodologies.</li> <li>2. Utilization of mathematical concepts in problem-solving.</li> <li>3. Integration of knowledge from various engineering disciplines.</li> </ol>	3
	PO2	<ol style="list-style-type: none"> <li>1. Recognizing and defining complex engineering problems or opportunities.</li> <li>2. Structuring and abstracting the problem for systematic analysis.</li> <li>3. Examining research literature</li> </ol>	3
CO5	PO1	<ol style="list-style-type: none"> <li>1. Application of scientific principles and methodologies.</li> <li>2. Utilization of mathematical concepts in problem-solving.</li> </ol>	2

	PO2	1. Recognizing and defining complex engineering problems or opportunities. 2. Structuring and abstracting the problem for systematic analysis. 3. Examining research literature	3
	PO3	1. Investigate and define a problem while identifying constraints, including environmental, sustainability, health, and safety considerations. 2. Understand customer and user needs while considering factors such as aesthetics.	2
	PSO1	1. Fundamental engineering knowledge 2. Thermal engineering concepts 3. Design and development skills	3
	PSO2	1. Product development 2. Identification of industrial challenges	2
	PSO3	1. Entrepreneurial skills	1

**29. TOTAL COUNT OF KEY COMPETENCIES FOR CO – (PO, PSO) MAPPING:**

Course Outcomes	PROGRAM OUTCOMES												PSOs		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO3 4
	4	10	10	10	4	5	4	4	10	5	10	8	4	4	
CO1	2	5	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	2	-	-	4	-	-	-	-	-	-	3	2	-
CO3	2	4	-	5	-	-	-	-	-	-	-	-	3	-	-
CO4	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	2	3	2	-	-	-	-	-	-	-	-	-	3	2	1

**30. PERCENTAGE OF KEY COMPETENCIES FOR CO – (PO/ PSO):**

Course Outcomes	PROGRAM OUTCOMES												PSOs		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO3 4
	4	10	10	10	4	5	4	4	10	5	10	8	4	4	
CO1	50	50	-	-	-	-	-	-	-	-	-	-	-	-	
CO2	-	-	20	-	-	80	-	-	-	-	-	-	75	50	
CO3	50	40	-	50	-	-	-	-	-	-	-	-	75	-	

CO4	75	30	-	-	-	-	-	-	-	-	-	-	-	-	-	
CO5	50	30	20	-	-	-	-	-	-	-	-	-	-	75	50	25

### 31. COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S, CO'S and PSO'S on the scale of 0 to 3,

0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

0 -  $0 \leq C \leq 5\%$  – No correlation,

2 -  $40\% < C < 60\%$  – Moderate

1-5  $< C \leq 40\%$  – Low/ Slight

3 -  $60\% \leq C < 100\%$  – Substantial /High

Course Outcomes	PROGRAM OUTCOMES												PSOs		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO1	2	2													
CO2			1										3	2	
CO3	2	1		2		3							3		
CO4	3	1													
CO5	2	1	1										3	2	
<b>Total</b>	9	5	2	2	-	3	-	-	-	-	-	-	9	4	1
<b>Average</b>	1.8	1.25	1	2	-	3	-	-	-	-	-	-	3	2	1

### 32. ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE	✓	Seminars	-
Objective / quiz	✓	Viva-Voce / PPT	✓	MOOCS	-
Assignments	✓	Project	-		

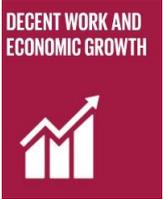
### 33. ASSESSMENT METHODOLOGY INDIRECT:

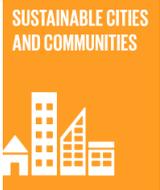
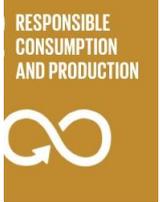
✓	Course End Survey (CES)
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### 34. RELEVANCE TO SUSTAINABILITY GOALS:

Thermal Engineering, as a versatile and powerful programming language, can play a significant role in advancing various SDGs.

x	1		NA
✓	2		NA

✓	3	 <p>GOOD HEALTH AND WELL-BEING</p>	NA
✓	4	 <p>QUALITY EDUCATION</p>	<p><b>Quality Education:</b> Quality education in thermal engineering provides a strong foundation in understanding energy, heat, and work, essential for solving real-world challenges. It emphasizes both theory and practical skills, preparing students to work with energy systems like power plants and refrigeration. This knowledge enhances employability in industries focused on energy and thermal processes.</p>
x	5	 <p>GENDER EQUALITY</p>	NA
x	6	 <p>CLEAN WATER AND SANITATION</p>	NA
✓	7	 <p>AFFORDABLE AND CLEAN ENERGY</p>	NA
x	8	 <p>DECENT WORK AND ECONOMIC GROWTH</p>	<p><b>Decent work and economic growth :</b> thermal engineering plays a key role in promoting decent work and economic growth by optimizing energy efficiency and reducing waste in industries. This leads to more sustainable practices, lower costs, and the creation of energy-focused jobs. Advancements in thermodynamics also drive innovation in sectors like manufacturing and power generation, boosting economic development.</p>
✓	9	 <p>INDUSTRY, INNOVATION AND INFRASTRUCTURE</p>	<p><b>Industry innovation and infrastructure:</b> Thermal engineering is vital for industry innovation and infrastructure, as it drives advancements in energy-efficient technologies and sustainable engineering solutions. These innovations improve industrial processes and contribute to building more resilient and eco-friendly infrastructures.</p>
x	10	 <p>REDUCED INEQUALITIES</p>	NA

x	11	 <p>SUSTAINABLE CITIES AND COMMUNITIES</p>	NA
x	12	 <p>RESPONSIBLE CONSUMPTION AND PRODUCTION</p>	<b>Responsible consumption and production:</b> optimizing energy use and minimizing waste in industrial processes. By improving efficiency, it supports sustainable practices that reduce environmental impact and conserve resources.
✓	13	 <p>CLIMATE ACTION</p>	<b>Climate Action:</b> Thermal engineering is essential to climate action by enabling the development of energy-efficient technologies that reduce greenhouse gas emissions. It supports the transition to renewable energy sources and sustainable systems, helping mitigate the effects of climate change.
x	14	 <p>LIFE BELOW WATER</p>	NA
x	15	 <p>LIFE ON LAND</p>	NA
x	16	 <p>PEACE, JUSTICE AND STRONG INSTITUTIONS</p>	NA
x	17	 <p>PARTNERSHIPS FOR THE GOALS</p>	<b>Partnerships for the Goals:</b> This syllabus promotes collaboration among students from diverse fields in multidisciplinary teams, fostering partnerships for the development of innovative and sustainable engineering solutions that align with global sustainability goals.

**Signature of Course Coordinator  
Name & Designation**

**HOD**